EQUILIBRIUM

Introduction

Chemical reactions do not always go to completion. In these systems there are two reactions that are in competition: the forward reaction and the reverse reaction. The **forward reaction** is reversible where the reactants produce products. The **reverse reaction** is a reversible as well, it is where the products are turned into their original reactants. When the rate of the forward reaction is equal to the rate of the reverse reaction, the system is said to be at **equilibrium** since the concentration of products and reactants is constant.

A system will remain at chemical equilibrium unless the conditions change. Once you subject a system to a disturbance, it will respond to this stress by **shifting** to accommodate the new conditions by relieving the stress and a new equilibrium will eventually be reached. This is known as **Le Chatelier's principle**. If the forward reaction dominates the system, it is said to be shifting to **the right**. If the reverse reaction dominates the system, it is said to be shifting to **the left.** When it comes to heat, an **endothermic** reaction shifts right and an **exothermic** shifts left.

In this experiment, you will be analysing two equilibrium systems and seeing which way the equilibrium shifts by observing the resulting colour change due to stress.

The first system is that of ferric chloride ($FeCl_3$) and ammonium thiocyanate (NH_4SCN).

$$\mathbf{Fe^{3+}{}_{(aq)} + 6\ SCN^{-}{}_{(aq)} \rightleftarrows [Fe(SCN)_6]^{3-}{}_{(aq)}}$$

This reaction produces one complex ion that is a deep red colour. You will be able to see the shift of equilibrium that induces a colour change from the original solution.

The second system involving the formation of two complex ions between cobalt and water.

$$\mathbf{Co(H_2O)_6{}^{2+}{}_{(aq)} + 4\ Cl^{-}{}_{(aq)} \rightleftharpoons CoCl_4{}^{2-}{}_{(aq)} + 6\ H_2O_{(l)}}$$

The colour of the solution of cobalt (II) ion is pink in water and this is due to the complex ion formed between Co^{2+} and H_2O. Once the chloride from the hydrochloric acid (HCl) is added, the colour changes to blue due to the reaction between Co^{2+} and Cl^-.

Purpose

The purpose of this experiment is for students to observe equilibrium shifts during chemical reactions in order to visualise Le Chatelier's principle.

Hypothesis

What is your hypothesis concerning the direction both of the equilibriums will shift?

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Materials

- $FeCl_3$ solution, 0.1M
- NH_4SCN solution, 0.1M
- $CoCl_2$ aqueous solution, 0.1M
- HCl solution, 12M
- $AgNO_3$ solution, 0.1M
- Distilled water
- 1 x 100mL beaker
- 2 x 50mL beakers
- 3 x 30mL beakers
- 1 x 10mL Graduated cylinder
- 9 x Large test tubes
- Test tube rack
- Ethanol
- Stirring rod
- 2 x pipettes
- Ice Bath
- Hot Water Bath (80^{o}C)]
- Stopper

Notes on materials:

Beakers can be used instead of test tubes; it is just dependent on what you have more of in stock.

Potassium thiocyanate can be used instead of ammonium thiocyanate. Iron (III) nitrate can be used instead of ferric chloride.

Safety

Concentrated HCl should be used under a fume hood as it is toxic upon inhalation and is corrosive to skin an eyes causing severe burns.

Silver nitrate will stain clothing and skin.

Wear safety google and a lab coat/apron throughout the whole experiment. Wear chemical resistant gloves if possible when using HCl.

Procedure and data

Part 1: Iron-thiocyanate equilibrium

1. Observe from the stock solution:

   The colour of the NH_4SCN solution: ____

   The colour of the $FeCl_3$ solution: ____

2. Label two 50mL beakers: NH_4SCN and $FeCl_3$.

3. Pour 10mL of NH_4SCN and 10mL of $FeCl_3$ into their designated beakers.

4. Add 50mL of distilled water to the 100mL beaker.

6. Add 1mL of $FeCl_3$ and 1mL of NH_4SCN to the distilled water and stir.

   The colour of the new solution: ____

7. Label the four test tubes: 1, 2, 3, 4

8. Pour 10mL of the solution from step 6 into each test tube.

9. To test tube 2 add 2mL of $FeCl_3$ and stir.

   Compare the colour of test tube 1 and 2: ____

10. To test tube 3, add 2mL of NH_4SCN and stir.

    Compare the colour of test tube 1 and 3: ____

11. To test tube 4, add 2 mL of NH_4Cl and stir.

    Compare the colour of test tube 1 and 4: ____

Part 2: Cobalt (II) chloride equilibrium

1. Observe from stock solution:

The colour of $CoCl_2$: ____

2. Label three test tubes: 1, 2, 3. Make sure test tubes are clean and dry.

3. Add 6mL of $CoCl_2$ to test tube 1.

4. Add 8mL of HCl to test tube 1.

The colour of the new solution: ____

5. Transfer 4mL of the solution into test tube 2.

6. Add distilled water drop by drop to test tube 2 until a pink colour is established.

What has occurred in tube 2:

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7. Transfer 4mL from test tube 1 into test tube 3.

8. To test tube 3, add $AgNO_3$ solution drop by drop until a colour change. Stopper the test tube once the colour has changed.

Observations of test tube 3: ____

9. To test tube 1, add distilled water drop by drop until it is purple/lavender.

10. Equally divide the solution from test tube 1 into three 30mL beakers.

11. Place one beaker in the ice bath.

12. Place one beaker in the hot water bath

13. Leave one beaker at room temperature (control sample).

14. Compare the colours of the solutions after 10 minutes.

Colour of beaker from ice bath: ____

Colour of beaker from water bath: ____

Colour of the control sample: ____

Results

Part 1:

1. a) Why did a colour change occur when $FeCl_3$ was added to the NH_4SCN?

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What direction (left or right) did the equilibrium shift when the following reagents were added? Explain your reasoning using terms related to Le Chatelier's principle.

$$\mathbf{Fe^{3+}_{(aq)} + SCN^{-}_{(aq)} \rightleftarrows FeSCN^{2+}_{(aq)}}$$

pale yellow	colourless		deep red

b) Addition of $FeCl_3$:

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c) Addition of NH_4SCN:

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d) Addition of NH_4Cl:

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Part 2:

1. Use the following equilibrium equation to explain your observation:

$$Co(H_2O)_6^{2+}{}_{(aq)} \quad + \quad 4\ Cl^{1-}{}_{(aq)} \quad \rightleftharpoons \quad CoCl_4^{-2}{}_{(aq)} \quad + \quad 6\ H_2O_{(l)}$$

Explain, using terms related to Le Chatelier's principle, which direction the equilibrium shifted when HCl was added to the $CoCl_2$ solution.

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2. Comparing the colours from the three beakers from step 11-13 and with your understanding of Le Chatelier's principle, determine whether or not the following reaction is endothermic or exothermic. Explain.

$$CoCl_4^{2-}{}_{(aq)} \quad \rightarrow \quad Co(H_2O)_6^{2+}{}_{(aq)}$$

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